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Concussions in Paralympic Sports: A Systematic Review

Gehirnerschütterungen im Paralympischen Sport: ein systematischer Review

REVIEW

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Summary

› **Introduction:** The Paralympic movement has grown rapidly over the last few years. As participation in Para sports increases, so do its sport-related injuries. A particular injury constitutes sport-related concussions (SRC). However, the data regarding its epidemiology in Para sports has been inadequately researched. Therefore, this review aimed to investigate the occurrence of SRC in Para sports.

› **Methods:** A systematic literature review was conducted according to PRISMA guidelines.

› **Results:** 13 articles were included in this review. Wheelchair Basketball, Sledge Hockey, Blind Football, Para Swimming, Para Judo, and Para Skiing are most commonly affected by SRC. Sledge hockey reported 4.5 SRC per 1000 athlete sports exposure hours (AEH) and Para Swimming reported 0.5-0.6 SRC per 1000 AEH. Visually impaired athletes reported 1.24 SRC per 1000 AEH. Women reported 0.8 SRC per 1000 AEH whereas men reported 0.3 per 1000 AEH.

› **Discussion:** Para sports such as Wheelchair Basketball, Sledge Hockey, Blind Football, Para Swimming, Para Judo, and Para Skiing are differently affected by SRC compared to non Para sports. The increased incidence in Para Swimming and visually impaired athletes can be explained by the respective conditions due to different disabilities. The high incidence of SRC in women is similar to observations in non Para sports. Despite reported studies, SRC in Para sports may still be underreported.

KEY WORDS:
Para Sports, Sport-Related Concussions (SRC), Injuries, Para Athletes, Competition

Introduction

Para sport, or sport for the disabled, describes the sport practiced by people with disabilities. Paralympic sports have continued to increase in popularity over recent years. The Rio 2016 Summer Paralympic Games witnessed the largest cohort of athletes participating at the event, namely 4378 athletes competing in 22 sports (4). With the growing interest and participation in such events, the protection of the health of the athlete and efforts to reduce both injury and illness in this population remain foremost on the agenda of the International Paralympic Committee (IPC) (4, 32).

Since the 2002 Winter Paralympics in Salt Lake City and the 2012 Summer Olympics in London, epidemiological data of participating athletes have been recorded in an internationally standardized manner with the Web-Based Injury and Illness Surveillance System (WEB-IISS) (18, 32). Here, the participating countries' medical attendants reported the injuries and illnesses of the respective Paralympic athletes. Injury frequency and injury types differed greatly from non-disability sports. Body regions such as the upper body and the spine are more frequently affected in Paralympic sports than the lower body (18).

A common injury of the upper body constitutes sport-related concussions (SRC). SRC concerns mild traumatic brain injuries (mTBI) caused by a direct blow to the head, neck, or body resulting in an impulsive force being transmitted to the brain, which commonly occurs in sports (26, 27). It is associated with several short-term (e.g., headache, unsteady gait, dizziness, and/or loss of consciousness) to long-term (neurological diseases, chronic traumatic encephalopathy (CTE), dementia, or vestibular dysfunction) impairments (14, 15, 27).

Since 2016, the monitoring system for injuries has included specific questions about SRC, so that injuries are not only recorded by body region, but injuries to the head, face, and neck are also registered (9, 18). However, the data about SRC in Para athletes remains limited. A first position statement on SRC in Para sport was published in 2021 and addresses specific issues Para athletes are faced with (34). The SRC experience of the Para athlete is unique, due to the interaction of the individual's primary impairment and the pathophysiology of SRC (27). Therefore, SRC in Para sports may be underestimated. ›

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Table 2

Concussions in Paralympic Sports. Included studies.

REFERENCE	DESIGN	ATHLETE / PLAYER SPORTS EXPOSURE DURATION	MAIN RESULTS
(3) Curtis KA et al. (1985)	Survey	4·35±1·76 days per week	2% SRC reported out of total 291 injuries.
(4) Derman et al. (2017)	Survey	51198 days	No reported SRC.
(5) Derman W. et al. (2020)	Prospective cohort study	6804 days	2 SRC in Alpine Skiing and 2 SRC in Para Ice hockey reported out of total 142 injuries.
(11) Ferrara et al. (2000)	Longitudinal Study	13 - 24 days	3 SRC out of 1037 total injuries reported.
(12) Hawkeswood et al. (2011)	Survey	Not reported	SRC were reported to be among the most common (8 out of 10 respondents) injuries and highest-ranked specific injury (6 out of 10 respondents).
(19) Hollander et al. (2020)	Prospective injury surveillance study	940 matches 3696 days	No SRC were reported. Unreported minor SRC estimated to be prevalent in half of the cases.
(21) Lexell et al. (2021)	Descriptive epidemiological study	6.8±4.8 hours per week	13 SRC or 0.5 SRC per 1000 athlete exposure hours reported (9.3% of all reported injuries).
(22) Magno e Silva et al. (2012)	Descriptive epidemiological study	23 matches	No SRC reported.
(23) McCormack DA et al.(1991)	Survey	Not reported	7 SRC out of total 346 reported injuries.
(29) Sobry AJ et al. (2022)	Survey	Individual to each player	4.5 SRC per 1000 Athlete exposure hours reported (range 2.6-7.3).
(30) Webborn et al. (2006)	Prospective injury surveillance study	Not reported	1 SRC out of 24 total injuries reported in Alpine skiing.
(31) Webborn, Willick & Emery (2012)	Descriptive epidemiological study.	Not reported	In Nordic skiing and biathlon, 2 SRC out of 26 total injuries reported.
(35) Wessels et al. (2012)	Survey	Not reported	6.1 % out of 263 participants reported SRC.102 SRC reported. 30.6% of women and 14.36% of men reported a previous SRC.

When comparing SRC incidence in Paralympic with non Paralympic disciplines, most appear in sports such as ice hockey, American football, and/or soccer (13, 36). For example, injury incidence rates at Ice Hockey World Championship games ranged from 0.7 in 2007 to 1.6 in 2012. 10% (N=160) of sports injuries constituted SRC (10). Kissick and Webborn evaluated Paralympic sports based on impairment, impact velocity, impact potential, and head protection, and created a risk rating for potential SRC (20). From this evaluation, the sports with the highest risk of SRC were Road Cycling, Football 5-a-side (blind football or blind soccer), Para Triathlon (with the bike), Para Alpine Downhill, Para Alpine Slalom, and Para Biathlon. However, Para Ice Hockey was rated as low risk, although its Olympic counterpart is characterized by high incidence rates (20). Because of these contradictory findings, it is necessary to investigate the incidence rate of SRC in Para sports in general.

Kissick and colleagues described that the ratio of publications related to Para athletes constitutes 1:100 when compared to athletes without disabilities (20). Additionally, there is a deficit of research in the field of SRC in Para sports because systematic monitoring of injuries takes place only at Paralympic events (20). Because the most recent position statement of SRC stated that diagnosis and management of potential SRC in Para athletes is challenging with limited data (27), we aim to systematically review the existing data about SRC in Para sports to gain knowledge about its incidence and mode.

Methods

A systematic literature review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines (25).

Search Terms and Databases

The systematic search strategy and eligibility criteria were developed using the PICO scheme (24). The four inclusion criteria were defined as follows: (P) Patients/Participants: Athletes with a disability regardless of performance level; Paralympic athletes. (I) Intervention: data collection on sport-related concussions in disability sports. (C) Comparison: descriptive data on the epidemiology of sport-related concussions in disability sports. (O) Outcome: epidemiology of sport-related concussions in disability sports.

Two literature searches were conducted in the electronic databases Web of Science, PubMed, and SPORTDiscus. The following terms were utilized:

1. (Concussion) AND (Occurrence OR Incidence OR Appearance) AND ("Para Sport" OR "Disabled" OR "Disabled Athlete" OR Para* OR Disab* OR Wheelchair OR Blind OR Handicapped) AND (Sport OR Athlete*) NOT (High School) NOT (NFL) NOT (national football league)
2. (Concussion OR Brain Damage, SRC, Sport-Related Concus-

sion, Brain Injury*) AND (Occurrence OR Incidence OR Appearance) AND (Para* OR Disabled Sport) NOT (High School) NOT (NFL) NOT (national football league)

All articles from the year 1940 to the year 2023 were extracted from the databases. After duplicates were removed, publications were matched against inclusion and exclusion criteria based on the headings and abstracts and finally with the other information in the full text (figure 1). Decisive for the final selection was the relevance of the research question and the defined quality criteria regarding the study design.

Study Selection and Data Extraction

The identified studies from the electronic databases were transferred into a record management software for further screening. The whole screening process was in line with the mentioned eligibility criteria. In the beginning, all duplicates were removed. In the final step of the screening phase, the articles were screened in full-text version and, again, if necessary, removed if not matching the eligibility criteria.

Risk of Bias

For each article that met the inclusion criteria, the risk of bias was independently rated by two raters using the Downs and Black checklist (7). In case of an occurred discrepancy between the two raters, the issue of interest has been discussed with a third independent rater.

Results

1938 studies were identified by the application of the presented search terms. Of these 1938 studies, 542 duplicates were removed. Out of the 1396 screened records 1330 records were removed because they did not meet the inclusion criteria. 66 remaining studies were then reviewed based on their full-text versions. Additionally, 3 Studies were identified via manual search through cross-referencing. Finally, 13 studies were included in this review. A detailed overview of the decision-making process is shown in figure 1.

Risk of Bias Assessment

The risk of bias assessment of the included studies did not show any inter-rater conflicts between the two raters. Additional data on individual quality scores are provided in table 1 in the supplementary material.

Study Characteristics

The included studies consist of six surveys and seven observational studies (3, 4, 5, 11, 12, 19, 21, 22, 23, 29, 30, 31, 35). Six studies investigated Paralympic events (4, 5,11, 22, 30, 31). All the details of the included studies have been provided in table 2.

Findings

For the overall Paralympic games, Ferrara and colleagues reported 3 SRCs out of a total of 1037 reported injuries (11). In 2021, Lexell and colleagues assessed the incidence proportion and incidence rate of SRC in elite Para athletes across various disciplines, over a period of 52 weeks (21). They reported a total number of 13 SRCs with an incidence rate of 0.5 per 1000 athlete sports exposure hours (AEH) (21). Also, for the sport of Para swimming and Para judo, 2 SRCs each were reported out of the total 13 SRCs (21). Furthermore, in wheelchair basketball, 6.1% of the participants reported SRC (35). In Winter Paralympic sports, Sledge hockey reported an incidence rate of 4.5 SRC per 1000 AEH (29). Additionally, Para alpine skiing reported 1

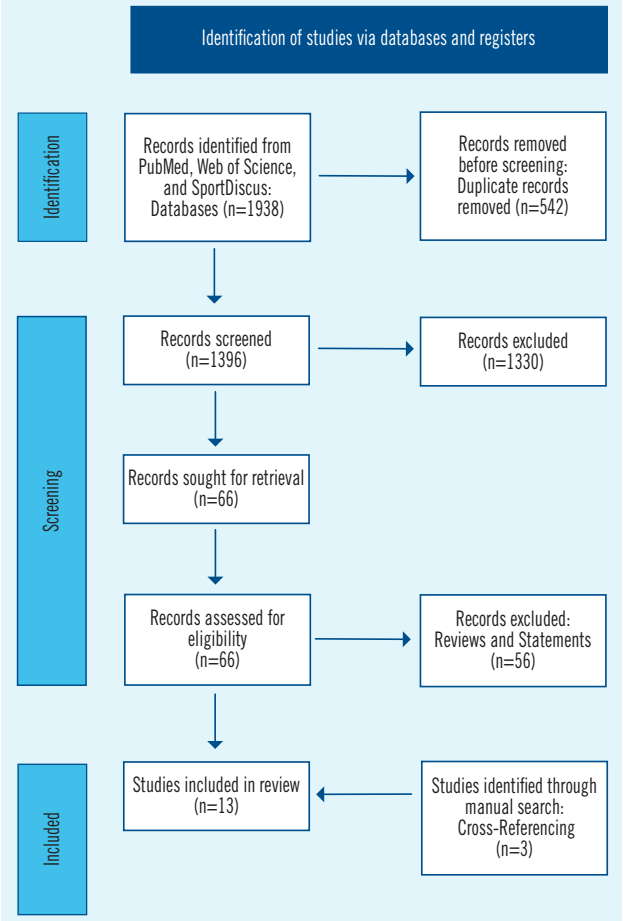

Figure 1

Overview of the decision-making process for the included studies.

SRC out of total of 24 injuries in the 2002 winter Paralympic games (30) and 2 SRCs out of 142 total injuries in the 2018 winter Paralympic games (5). Para Nordic skiing including biathlon reported 2 SRCs out of 26 total injuries (31). Furthermore, an incidence rate of 1.24 SRC per 1000 AEH was observed for visually impaired athletes, 0.3 SRC per 1000 AEH for physical deformities, and 0.7 SRC per 1000 AEH for athletes with spinal cord injury (21). Women reported an incidence rate of 0.8 SRC per 1000 AEH and men reported 0.3 SRC per 1000 AEH (21).

Discussion

The present study examined the incidence of SRC in Para sports. Thirteen studies were included in this review. The results showed that SRC in Paralympic sports differs among the disciplines. Sledge hockey had the highest incidence rate of SRC. Furthermore, Sledge hockey and Para swimming had higher SRC incidence than their able-bodied counterparts. Basketball showed similar incidence rates for both groups. Visually impaired and female Para athletes were more affected by SRC than the athletes with other impairments and male Para athletes respectively.

In Para swimming, 15% SRC (n=2 out of 13 total SRC) were reported with an incidence rate of 0.5-0.6 per 1000 AEH (21). Generally, swimming is not characterized by high rates of SRC as the incidence rate is approximately 0.03 per 1000 AEH in able-bodied swimmers (1). For Para swimmers, the sports classes vary according to the physical and vision impair- ›

ment with the lower numbers denoting higher severity of the impairment (28). A higher incidence of SRC can be reported in Para swimming because depending on the Para swimmer's underlying medical condition, their swimming biomechanics, compensatory biomechanics, and techniques to accommodate an impairment, can be altered (28). This in turn can affect their motor control and coordination, which can result in inaccurate perception of their sport surrounding or the pool. This can result in not being able to adeptly control their speed and direction causing collision with walls or even other swimmers, thereby increasing the probability of SRC (16). Furthermore, swimmers with dysmelia must use their heads to stop the timer, which is not considered an SRC but involves decreased neurobehavioral functions after several hits to the wall (16).

Also, similar to able-bodied swimmers having variability within the same age group, within each sport class every Para swimmer can have a distinct swimming performance, reflective of their training, experience, and athleticism, which is not affected by their impairments (28). Therefore, SRC prevention programs should be specifically designed for individual Para swimmers due to the difference in training needs based on underlying medical conditions, impairments, and function.

In wheelchair basketball, an incidence ratio of 8% SRC (n=1 out of 13 total SRC) out of total injuries was reported with an incidence rate of approximately 0.3 per 1000 AEH (21). In non Para basketball, an incidence of 0.2 - 0.5 SRC per 1000 AEH is observed (6). Basketball in itself constitutes a contact sport with high accelerations or speed that comes with a high risk of SRC. Contact has been a decisive factor contributing to high incidence of SRC in sports (12). Wheelchair basketball has safety rules like a protective horizontal bar on the wheelchair and anti-tip devices to prevent tipping or having wheel hubs without protrusions or sharp edges to prevent injuring other players and protect the playing surface. However, even with these measures it was found to have a similar rate of SRC as basketball. This can be ascribed to Para athletes having decreased muscle control, traveling at greater speeds, having a higher center of mass, or even the wheelchair setup being an unstable setup with higher risks of tipping over (3, 23, 35). These factors can be the reason for increased collisions or causing them to fall from the wheelchairs exposing them to a higher probability of getting an SRC, more so because their muscle control to protect themselves during a collision or a fall is decreased.

In Para judo 15% (n=2 out of 13 total SRC) SRC were reported with an incidence rate of 0.5-0.6 per 1000 AEH (21). A high incidence rate may be grounded in the fact that Para judo is mostly practiced by athletes with visual impairments. This can diminish the proprioceptive abilities of the athletes (8), possibly increasing the risk of SRC caused by being thrown to the floor or decreased ability to accurately dodge being hit by an opponent. Additionally, it can be a result of being thrown in an unexpected direction (21). In fact, sports with visually impaired athletes showed principally a higher SRC incidence than other impairments such as physical deformities or athletes with spinal cord injury (21, 22).

In Football 5-a-side sports in Brazilian football players with visual impairment, there was no report for SRC (22). However, it was stated that "A head injury is of great concern to the healthcare team, because it can lead to concussion" and 8.6 % (n=3 out of 35 total injuries) head injuries were reported (22). Injury surveillance data from the London 2012 and Rio 2016 Paralympic Games showed that blind football was the Para sport with the highest injury incidence per 1000 hours and at the London 2012 Paralympics, 13.6% of these injuries were to the head and face, also confirming that the blind footballers may be at risk for SRC (4,33). Blind football has a special set of rules such as speed limits, calling out before tackling, or no headers for the player's safety. However, the inability to perform a preliminary observation of the training or competition environment puts them at a disadvantage and more susceptible to sports injuries such as SRC (8). Moreover, since vision plays a pivotal role in the balance of an individual (17), it might further impair the athlete's core stability thereby making them prone to falls during various maneuvers. Thus, visually impaired athletes seem to be at a particularly high risk of experiencing SRC.

Para winter sports are characterized by variable incidence of SRC in Sledge Hockey (Para ice hockey), Para alpine skiing, Para Nordic skiing, and biathlon (5, 30, 31). The SRC incidence rate in sledge hockey teams was found to be substantially high (29). However, SRC accounted for 0.5 – 0.9 per 1000 AEH of ice hockey-related head injuries in non Para athletes (37). In both sledge hockey and ice hockey, bodychecking accounted for a major portion of SRC (12). However, the increased risk in sledge hockey may be due to the dasherboards that are commonly above the player's seated height with the bottom boards being very rigid as compared to the flexible transparent shields located above (12). Also, a sledge athlete's propulsion is gained almost entirely through upper body motion, which causes a greater momentum of the athlete at the moment of contact during a bodycheck, when compared to the same maneuver by a regular ice hockey player (12). Thus, sledge hockey is characterized by a very high SRC incidence rates, that must be further investigated to better protect the athletes.

During the 2002 Winter Paralympics, 1 SRC (out of 24 total reported injuries) was reported in Alpine skiing (30) and an incidence rate of 0.3 per 1000 athlete days (1.4% of all injuries) was reported in the 2018 Paralympic winter games (5). In Nordic skiing and biathlon, 7.7% of all injuries were reported to be SRC (31). Para winter sports have high vigilance and safety measures, such as having an aid for the athletes. Winter sports with their unpredictable environment paired with breakneck speeds are inherently considered extreme sports and have a high incidence of injuries including SRC. Combining this with the disabilities the Para athletes already possess, a much higher probability of SRC arises.

A trend followed similarly by both Para and non Para athletes in every sport is having a higher incidence of SRC in women than men (19,21,35). In Para athletes, women have an incidence rate, which is 2.5 times that of men (21). Decreased neck strength causing greater peak head and neck acceleration, neuroanatomical differences (such as greater area of unmyelinated neuronal processes), and willingness to report an injury can be the possible reasons (2). However, literature concerning the incidence of SRC in female Para athletes is scarce, and further evaluation of the epidemiology is recommended.

One limitation of the study is the inconsistent definition of 'head injuries' in some articles, ranging from mTBI to minor injuries like abrasions or neck injuries, including SRC. This has to be addressed in further studies to better understand the consequences of an SRC. Another limitation is the unavailability of the exact athlete sports exposure duration or incidence rates in some reported articles. This makes it difficult to compare the incidence rates of SRC for different sports. Additionally, some of the reported studies had the participant's self-reports, which can raise questions regarding the accuracy of the obtained data. However, Para athletes concern a diverse and understudied cohort with limited resources related to medical support. Therefore, we believe that self-reports are still feasible

in such athletes. Still, for further research different data collection modalities should be utilized to broaden the data set and our knowledge. In particular, the fact there is availability of up-to-date methods that can address behavioral and neurophysiological changes after head impacts in Para athletes (16) we should explore different methods to obtain objective and reliable data. Lastly, instances of SRCs are frequently not fully disclosed, primarily due to insufficient awareness of symptoms and their potential consequences (21). This results in the underreporting of SRC.

Conclusion

This study was conducted to reveal the incidence of SRC in Para sports. Sledge hockey and Para swimming have a higher SRC incidence rate as compared to their able-bodied peers. Basketball demonstrated a similar SRC incidence to the non Para athletes. Additionally, athletes with visual impairments and women are affected by a particularly high incidence rate of SRC. Because data assessment is insufficient in Para sports and screening tools are not easily transferable to the heterogeneous impairments that the Para athletes are faced with, the number might even be underestimated. However, first attempts are being made to improve diagnosis in Para athletes by applying advanced neuroimaging and behavioral methods (16). Given the reality of sports economics, characterized by low financial contributions from federations through low licensing and sponsorship revenues, fewer opportunities to train, and few marketable events, Para athletes must take advantage of the few opportunities to be present at major sporting events to finance and sustain their careers. Therefore, the investigation of SRC in Para sports must be increased to gain more insights into their occurrence and potential health impact on Para athletes.

Summary Box

Para sports are as affected by sport-related concussions (SRC) as the non Para sports.

A systematic review revealed that Wheelchair Basketball, Sledge Hockey, Blind Football, Para Swimming, Para Judo, and Para Skiing constitute the most affected disciplines. Visually impaired athletes and female Para athletes showed particularly high incidences of SRC in Para sports.

Conflict of Interest

The authors have no conflict of interest.

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References

(1) **Boltz AJ, Robison HJ, Morris SN, D'Alonzo BA, Collins CL, Chandran A.** Epidemiology of Injuries in National Collegiate Athletic Association Men's Swimming and Diving: 2014-2015 Through 2018-2019. J Athl Train. 2021; 56: 719-726. doi:10.4085/1062-6050-703-20

(2) **Covassin T, Moran R, Elbin RJ.** Sex Differences in Reported Concussion Injury Rates and Time Loss from Participation: An Update of the National Collegiate Athletic Association Injury Surveillance Program From 2004-2005 Through 2008-2009. J Athl Train. 2016; 51: 189-194. doi:10.4085/1062-6050-51.3.05

(3) **Curtis KA, Dillon DA.** Survey of wheelchair athletic injuries: common patterns and prevention. Spinal Cord. 1985; 23: 170-175. doi:10.1038/sc.1985.29

(4) **Derman W, Runciman P, Schwellnus M, Jordaan E, Blauwet C, Webborn N, Lexell J, van de Vliet P, Tuakli-Wosornu Y, Kissick J, Stomphorst J.** High precompetition injury rate dominates the injury profile at the Rio 2016 Summer Paralympic Games: a prospective cohort study of 51 198 athlete days. Br J Sports Med. 2018; 52: 24-31. doi:10.1136/bjsports-2017-098039

(5) **Derman W, Runciman P, Jordaan E, Schwellnus M, Blauwet C, Webborn N, Lexell J, van de Vliet P, Kissick J, Stomphorst J, Lee YH, Kim KS.** High incidence of injuries at the Pyeongchang 2018 Paralympic Winter Games: a prospective cohort study of 6804 athlete days. Br J Sports Med. 2020; 54: 38-43. doi:10.1136/bjsports-2018-100170

(6) **Dick R, Hertel J, Agel J, Grossman J, Marshall SW.** Descriptive epidemiology of collegiate men's basketball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. J Athl Train. 2007; 42: 194-201.

(7) **Downs SH, Black N.** The feasibility of creating a checklist for the assessment of the methodological quality both of randomized and non-randomised studies of health care interventions. J Epidemiol Community Health. 1998; 52: 377-384. doi:10.1136/jech.52.6.377

(8) **Duarte E, Silva HG, Vital R.** Aspects of sports injuries in athletes with visual impairment. Rev Bras Med Esporte. 2011; 17: 319-323. https: //www.scielo.br/j/rbme/a/P8nwtCJSJGbkXMsryLWhSbk/?format=pdf&lang=en [15 April 2024].

(9) **Echemendia RJ, Brett BL, Broglio S, Davis GA, Giza CC, Guskiewicz KM, Harmon KG, Herring S, Howell DR, Master CL, Valovich McLeod TC, McCrea M, Naidu D, Patricios J, Putukian M, Walton SR, Schneider KJ, Burma JS, Bruce JM.** Introducing the Sport Concussion Assessment Tool 6 (SCAT6). Br J Sports Med. 2023; 57: 619-621. doi:10.1136/bjsports-2023-106849

(10) **Engebretsen L, Steffen K, Alonso JM, Aubry M, Dvorak J, Junge A, Meeuwisse W, Mountjoy M, Renström P, Wilkinson M.** Sports injuries and illnesses during the Winter Olympic Games 2010. Br J Sports Med. 2010; 44: 772-780. doi:10.1136/bjsm.2010.076992

(11) **Ferrara MS, Palutsis GR, Snouse S, Davis RW.** A longitudinal study of injuries to athletes with disabilities. Int J Sports Med. 2000; 21: 221-224. doi:10.1055/s-2000-300

(12) **Hawkeswood J, Finlayson H, O'Connor R, Anton H.** A pilot survey on injury and safety concerns in international sledge hockey. Int J Sports Phys Ther. 2011; 6: 173-185.

(13) **Helmich I.** Game-specific characteristics of sport-related concussions. J Sports Med Phys Fitness. 2018; 58: 172-179. doi:10.23736/S0022-4707.16.06677-9

(14) **Helmich I, Reinecke KCH, Meuter K, Simalla N, Ollinger N, Junge R, Lausberg H.** Symptoms after sport-related concussions alter gestural functions. J Sci Med Sport. 2020; 23: 437-441. doi:10.1016/j.jsams.2019.11.013

(15) **Helmich I, Nussbaum N, Lausberg H.** Hyperactive movement behavior of athletes with post-concussion symptoms. Behav Brain Res. 2020; 380: 112443. doi:10.1016/j.bbr.2019.112443

(16) **Helmich I, Chang YY, Gemmerich R, Rodrigo L, Funken J, Arun KM, Van de Vliet P.** Neurobehavioral consequences of repetitive head impacts in Para swimming: A case report. J Sci Med Sport. 2024; 27: 16-19. doi:10.1016/j.jsams.2023.10.015

(17) **Helmich I, Gemmerich R.** Neuronal Control of Posture in Blind Individuals. Brain Topogr. 2024. doi:10.1007/s10548-024-01041-7

(18) **Hirschmüller A, Kosel J, Südkamp NP, Kubosch EJ.** Epidemiologie von Verletzungen und Überlastungsschäden vergangener paralympischer Spiele. Dtsch Z Sportmed. 2015; 66: 294-299. doi:10.5960/dzsm.2015.207

(19) **Hollander K, Kluge S, Glöer F, Riepenhof H, Zech A, Junge A.** Epidemiology of injuries during the Wheelchair Basketball World Championships 2018: A prospective cohort study. Scand J Med Sci Sports. 2020; 30: 199-207. doi:10.1111/sms.13558

(20) **Kissick J, Webborn N.** Concussion in Para Sport. Phys Med Rehabil Clin N Am. 2018; 29: 299-311. doi:10.1016/j.pmr.2018.01.002

(21) **Lexell J, Lovén G, Fagher K.** Incidence of sports-related concussion in elite Para athletes - a 52-week prospective study. Brain Inj. 2021; 35: 971-977. doi:10.1080/02699052.2021.1942551

(22) **Magno e Silva MP, Morato MP, Bilzon JL, Duarte E.** Sports injuries in Brazilian blind footballers. Int J Sports Med. 2013; 34: 239-243. doi:10.1055/s-0032-1316358

(23) **McCormack DA, Reid DC, Steadward RD, Syrotuik DG.** Injury profiles in wheelchair athletes: results of a retrospective survey. Clin J Sport Med. 1991; 1: 35-40. doi:10.1097/00042752-199101000-00005

(24) **Methley AM, Campbell S, Chew-Graham C, McNally R, Cheraghi-Sohi S.** PICO, PICOS, and SPIDER: a comparison study of specificity and sensitivity in three search tools for qualitative systematic reviews. BMC Health Serv Res. 2014; 14: 579. doi:10.1186/s12913-014-0579-0

(25) **Moher D, Liberati A, Tetzlaff J, Altman DG.** PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA Statement. Open Med. 2009; 3: e123-e130.

(26) **Noble JM, Hesdorffer DC.** Sport-related concussions: a review of epidemiology, challenges in diagnosis, and potential risk factors. Neuropsychol Rev. 2013; 23: 273-284. doi:10.1007/s11065-013-9239-0

(27) **Patricios JS, Schneider KJ, Dvorak J, Ahmed OH, Blauwet C, Cantu RC, Davis GA, Echemendia RJ, Makdissi M, McNamee M, Broglio S, Emery CA, Feddermann-Demont N, Fuller GW, Giza CC, Guskiewicz KM, Hainline B, Iverson GL, Kutcher JS, Leddy JJ, Maddocks D, Manley G, McCrea M, Purcell LK, Putukian M, Sato H, Tuominen MP, Turner M, Yeates KO, Herring SA, Meeuwisse W.** Consensus statement on concussion in sport: the 6th International Conference on Concussion in Sport-Amsterdam, October 2022. Br J Sports Med. 2023; 57: 695-711. doi:10.1136/bjsports-2023-106898

(28) **Salerno J, Tow S, Regan E, Bendziewicz S, McMillan M, Harrington S.** Injury and Injury Prevention in the United States Para Swimming: A Mixed-Methods Approach. Int J Sports Phys Ther. 2022; 17: 293-306. doi:10.26603/001c.31173

(29) **Sobry AJ, Kolstad AT, Janzen L, Black AM, Emery CA.** Concussions and Injuries in Sledge Hockey: Grassroots to Elite Participation. Clin J Sport Med. 2022; 32: e478-e484. doi:10.1097/JSM.0000000000001023

(30) **Webborn N, Willick S, Reeser JC.** Injuries among disabled athletes during the 2002 Winter Paralympic Games. Med Sci Sports Exerc. 2006; 38: 811-815. doi:10.1249/01.mss.0000218120.05244.da

(31) **Webborn N, Willick S, Emery CA.** The injury experience at the 2010 Winter Paralympic Games. Clin J Sport Med. 2012; 22: 3-9. doi:10.1097/JSM.0b013e318243309f.

(32) **Webborn N, Emery C.** Descriptive epidemiology of Paralympic sports injuries. PM R. 2014; 6: S18-22. doi:10.1016/j.pmrj.2014.06.003

(33) **Webborn N, Cushman D, Blauwet CA, Emery C, Derman W, Schwellnus M, Stomphorst J, Van de Vliet P, Willick SE.** The Epidemiology of Injuries in Football at the London 2012 Paralympic Games. PM R. 2016; 8: 545-552. doi:10.1016/j.pmrj.2015.09.025

(34) **Weiler R, Blauwet C, Clarke D, Dalton K, Derman W, Fagher K, Gouttebarge V, Kissick J, Lee K, Lexell J, Van de Vliet P, Verhagen E, Webborn N, Ahmed OH.** Concussion in Para sport: the first position statement of the Concussion in Para Sport (CIPS) Group. Br J Sports Med. 2021; 55: 1187-1195. doi:10.1136/bjsports-2020-103696

(35) **Wessels KK, Broglio SP, Sosnoff JJ.** Concussions in wheelchair basketball. Arch Phys Med Rehabil. 2012; 93: 275-278. doi:10.1016/j.apmr.2011.09.009

(36) **West SW, Pankow MP, Gibson ES, Eliason PH, Black AM, Emery CA.** Injuries in Canadian high school boys' collision sports: insights across football, ice hockey, lacrosse, and rugby. Sport Sci Health. 2023; 19: 1129-1137. doi:10.1007/s11332-022-00999-w

(37) **Zuckerman SL, Kerr ZY, Yengo-Kahn A, Wasserman E, Covassin T, Solomon GS.** Epidemiology of Sports-Related Concussion in NCAA Athletes From 2009-2010 to 2013-2014: Incidence, Recurrence, and Mechanisms. Am J Sports Med. 2015; 43: 2654-2662. doi:10.1177/0363546515599634